Fabry-Perot Etalons

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Experiment Overview

This experiment is taken by second year physics students and requires three hours to complete. This experiment involves observing interference fringes created by a laser that is shone through a Fabry-Perot etalon interferometer. The laboratory notes lead students from the known condition for interference maxima to a general equation for the radii of interference fringes (r_p) as a function of laser wavelength (l), fringe number (p), distance between etalon faces (d) and the focal length of the viewing lens (f), namely

$r_p = f\ (pl/d)^{1/2}$

Students will measure the position and corresponding ring number of each observed fringe, with these measurements and the above equation they will come to the conclusion that by using the slope of a graph of r_p vs $p^{1/2}$ they will be able to determine the distance d between the two faces of the etalon. Once the distance of the etalon is determined the, students repeat this process using a source of unknown wavelength (typically a green laser), and then apply what they've learned in the first part to to determine the wavelength of the second source.

It is also notable that the students who undertake the experiments in our second year physics subject do so in a Round-Robin style, and so some students will do this experiment in the middle of semester, while others will do it at the end, and thus may have differing amounts of background knowledge prior to their experience with this experiment.

Learning Experience

This experiment is one of five experiments that support the second year Physics subject at Flinders on (geometrical and wave) Optics and Lasers. It has a good scientific foundation, with results that are repeatable, reliable, and easily attainable within the three hour time limit. Students must make links between what they measure in the laboratory and abstract equations for interference patterns in order to achieve the experimental aims of the experiment.

This experiment was chosen for the ASELL workshop because the notes for the experiment have not been changed at all for several years and could do with improvement; including making the experiment more exciting and engaging for the students involved.

Aims and Objectives

The aim of this experiment is to determine the separation between the etalons by measuring the radii of successive interference fringes created by shining the red helium neon laser through the Fabry-Perot interferometer.

The second aim of this experiment is to determine the wavelength of a second light source of unknown wavelength (a green laser).

The objective of this experiment is to have students realise that inference phenomena can be used to determine key information about the properties of the incident light and devices in the optical train, including wavelength of the incident light, the distance between etalons or even the focal length of a lens.

This experiment also gives the students an opportunity to observe and interact with inference patterns in the laboratory instead of only reading about them and see pictures of inference patterns in books or lectures.

Level of Experiment

2nd Year physics experiment.

Keyword Descriptions of the Experiment

Domain
Fabry-Perot Etalons, Interference, Wave properties of light

Specific Descriptors
Fabry-Perot Etalons, Interference of light, Lasers, Optics

Course Context

Educational Aims

The aims of this topic are focussed on building a sound understanding of the fundamentals of optics. In addition to building an experimental understanding of the basic theories in these areas of physics, students will also critically examine theoretical concepts and continue to develop their computational and visualisation skills using Mathematica; and build experimental competence and confidence through directed laboratory exercises.

Expected Learning Outcomes

At the successful completion of this topic, students will have developed a sound knowledge of fundamental optical phenomena, namely Optics and Lasers. Students will:

- understand lenses, mirrors and the background science of optical systems;
- understand the wave properties of light, such as polarisation, interference and diffraction; and
- understand the basic principles of laser devices.

Furthermore students will be empowered to solve many basic scientific problems, and will begin to develop their professional skills in critical scientific thinking and problem solving, both theoretically and experimentally.

Syllabus

Material to be taught in this topic will be selected from Optics and Lasers: Geometrical optics; Wave nature of Light; Polarisation; Interference and diffraction; Coherence; Laser Theory; Laser types; and Laser applications.

From the above educational aims and expected learning outcomes of the topic it can be seen that this experiment covers an understanding of lenses, the wave properties of light and inference effects as well as familiarising students with simple low powered lasers.

Prerequisite Knowledge and Skills

Students require the following skills:

- Ability to mount and align optics on either an optical bench or optical rail.
- Students must be able to produce a straight line graph, determine the slope of that graph, then be able to apply their knowledge of the underlying physical relationships to measure specific optical properties.
- Make measurements using a vernier calliper.
- Be able to perform error analysis of experimentally determined values and be proficient in coping with complex mathematical relationships that describe them.

Knowledge requirement:

- Have an idea of how to determine the focal length of a lens
- Students must understand constructive and destructive interference of light, being familiar with the conditions for bright and dark fringes
- Students should understand how to produce linear plots to verify complex mathematical relationships between independent and dependent experimental variables.

Time Required to Complete

Prior to Lab: ~ 15 minutes (read through laboratory notes)
In Laboratory: 3 hours
After Laboratory: Nil ? Completed report to be handed up at the conclusion of lab time.

Experiment History

The Fabry-Perot etalon experiment has been run at Flinders University for over ten years as part of the laboratory component for the “Optics and Lasers” topic. In this time the experiment has undergone several minor changes, the first of which was replacing original light source (a mercury lamp and green filter) with a helium neon laser, which increased the optical brightness of the fringe pattern and made it easier to observe. A concave mirror of reasonable radius of curvature had been used to increase the divergence of the laser beam before it entered the Fabry-Perot etalon. This mirror has recently been replaced by a beam expander. While some aspects of the practical set up have changed, the aim of this experiment and the laboratory notes have remained largely unchanged for many years.

Comments

There is a section of the student notes that discusses Fabry-Perot applications with respect to laser cavities. This section introduces eight equations that are not used in the laboratory practical and may serve to confuse the aim of the experiment. This section should either be made relevant to the experiment (by introducing question or practical exercises related to the content) or alternatively it shoud probably be removed from the notes.

Students are asked to comment on the uncertainty of their calculated value of d (the distance between etalon) but are given no guidance for how to calculate this uncertainty. Similarly the students are asked to comment on the uncertainty of the calculated wavelength for the green laser without being given any guidance. This section of the experiment could be expanded to include a more in-depth discussion of the parts of this experiment that contribute to the uncertainties in the overall result by asking students specific questions about how the uncertainty in each parameter could influence their final results.

The authors seek feedback from the workshop participants on the ideas mentioned in this section.